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Short communication

Nondestructive leaf area estimation of 'Niagara' and 'DeChaunac' grapevines

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Abstract

Leaves were sampled from *Vitis labruscana* Bailey cv. 'Niagara' and the interspecific hybrid 'DeChaunac' grapevines several times during a 2-year investigation of leaf area estimation. Linear measurements of leaf length and width were made and correlated with leaf area measurements made with a computerized image processing system. For each cultivar, nine regression equations were derived and compared. Most models resulted in high ($R^2 = 0.90$) coefficients of determination, but the power model using leaf width provided a high R^2 and relatively low standard error of the estimate ('Niagara': area $= 0.637W^{1.995}$, $R^2 = 0.9821$, and S.E. $= 10.58$; 'DeChaunac': area $= 0.672W^{1.963}$, $R^2 = 0.9632$, S.E. $= 5.67$). Use of single-variable equations facilitates simple, rapid, and accurate estimation of 'Niagara' and 'DeChaunac' leaf area.
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Keywords: *Vitis labruscana*; *V. riparia*; *V. vinifera*; Grape leaf area

1. Introduction

Leaf area measurements are widely used in studies of grapevine physiology and in evaluation of viticultural practices. Knowledge of leaf area is an important parameter in understanding photosynthesis, light interception, water and nutrient use, crop growth, and yield potential (Smart, 1974, 1985; Williams, 1987).

Although accurate assessment of leaf area is a critical component in understanding physiological and agronomic processes, obtaining leaf area measurements is often costly, time-consuming, and destructive (Marshall, 1968). Estimating leaf area from equations

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using simple measurements of leaf dimensions is an inexpensive, rapid, and nondestructive alternative for accurately assessing grapevine leaf area. Investigations which correlate leaf length and width with leaf area are most common (Smith and Kliewer, 1984; Elsner and Jubb, 1988), but some studies also include petiole length (Manivel and Weaver, 1974) and leaf weight (Sepúlveda and Kliewer, 1983; Montero et al., 2000). Regression equations that incorporate leaf length and/or width are generally chosen for their simplicity and accuracy, and because these measurements are nondestructive.

Our objectives were to develop regression equations to estimate leaf area nondestructively for two grape cultivars widely grown in eastern North America, *Vitis labruscana* Bailey cv. 'Niagara', and 'DeChaunac'. 'Niagara' is a native American cultivar, while 'DeChaunac' is an interspecific hybrid (*V. vinifera*, 50%; *V. labruscana*, 16%; *V. rupestris*, 31%; *V. riparia*, 3%) (Galet, 1979).

2. Materials and methods

Leaves for this study were collected in 1993 and 1994 from two commercial vineyards in Yates Co., New York. Each vineyard had blocks of 'Niagara' and 'DeChaunac'. At one vineyard, 'Niagara' vines were 13 years old, while the 'DeChaunac' block was 20 years old. Both cultivars had been hedge-pruned since 1990. Up until 1990, the 'Niagara' block had been trained to top-wire bilateral cordons and the 'DeChaunac' had been Umbrella Kniffin trained. At the other vineyard, 30-year-old 'Niagara' were Umbrella Kniffin trained. 'DeChaunac' vines at this vineyard were 22 years old and had been hedge-pruned since 1990.

Methods of leaf collection varied between years. In 1993, 'Niagara' leaves were collected from the oldest block on 9 July and 1 October by randomly selecting two leaves from 50 vines throughout the block on each date. 'DeChaunac' leaves were collected from the oldest block on 21 and 29 July, and 2, 9, and 16 September by randomly selecting two leaves from 35 vines throughout the block on each date. Leaves were placed in ziplock plastic bags, and were transported on ice to the laboratory. Leaves were frozen until leaf dimensions and areas were measured. In 1994, 'Niagara' and 'DeChaunac' leaves were collected at both vineyards on 21 June, 12 July, and 29 August. Seven to twelve randomly chosen shoots were collected for each cultivar/vineyard/date combination. Leaves were removed from shoots in the field and treated as in 1993. Total sample size was 814 and 995 leaves for 'Niagara' and 'DeChaunac', respectively.

Selection of leaf dimensions for measurement was governed by variation in leaf characteristics (e.g., size, shape, and symmetry) and practical constraints (e.g., ease and accuracy of measurements under field conditions). Given these concerns, we chose maximum leaf width and midvein length to correlate with leaf area. Maximum leaf width (at the widest point perpendicular to the midvein) and midvein length were measured to the nearest 0.1 cm. Leaf area was then measured to the nearest 0.1 cm^2 using an Agvision Pseudocolor Image Analysis System (Decagon Devices Inc., Pullman, WA).

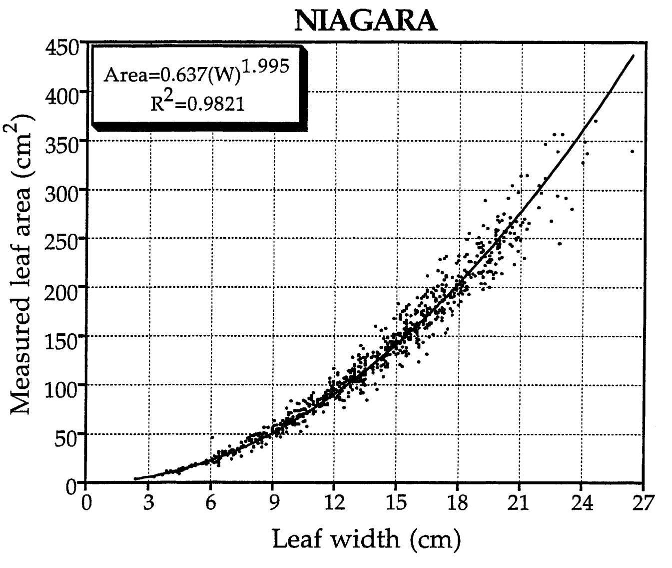
Linear relationships between leaf dimensions and leaf area were assessed for each cultivar using PROC UNIVARIATE and PROC REG (SAS Institute Inc., 1989). Where power models ($Y = aX^b$) were used, dependent and independent variables were subjected to natural logarithm transformations before analysis. We chose 'best' leaf area estimation equations based on values obtained for coefficients of determination (R^2), standard errors of estimates, and two-tailed t-tests for intercept equality to zero.

3. Results

Regression analysis demonstrated strong relationships between leaf area and maximum leaf width (W), midvein length (L), the product of width and length (WL), the square of width (W^2), and the square of length (L^2) (Table 1). However, suitability of these models varied based on the selection criteria previously described. For both cultivars, Eqs. (1), (2) and (5) had large negative intercept estimates that were significantly different from zero, and were eliminated from further consideration for this reason. Eq. (3) for 'Niagara', and Eqs. (3) and (4) for 'DeChaunac' also had intercept estimates significantly different from zero, and thus were rejected. Eq. (4) for 'Niagara' was eliminated because it had weaker values of coefficient of determination and standard error of the estimate than the remaining equations. Of the remaining four equations, Eq. (6) was the best two-variable model for each cultivar. Of the single-variable power models, those incorporating width (Eq. (8)) had greater coefficients of determination and smaller standard errors of estimates than models

Table 1
Regression equations, coefficients of determination (R^2), standard errors of estimates, and significance levels of intercepts for correlations between grape leaf area (A) and measurements of maximum leaf width (W) and midvein length (L)

Equation no.	Regression equation	R^2	S.E. of estimate (cm^2)	Intercept = 0 ($P > T$)
Niagara				
(1)	$A = -94.522 + 16.390W$	0.9441	17.42	0.0001
(2)	$A = -100.178 + 20.677L$	0.9118	21.89	0.0001
(3)	$A = 5.168 + 0.604W^2$	0.9645	13.89	0.0001
(4)	$A = 1.077 + 0.951L^2$	0.9362	18.62	0.4282
(5)	$A = -99.880 + 11.868W + 6.045L$	0.9502	16.46	0.0001
(6)	$A = 0.196 + 0.388W^2 + 0.366L^2$	0.9796	10.53	0.7987
(7)	$A = -0.474 + 0.782WL$	0.9777	10.99	0.5515
(8)	$A = 0.637W^{1.995}$	0.9821	10.58	0.0001
(9)	$A = 0.832L^{2.053}$	0.9564	16.50	0.0001
DeChaunac				
(1)	$A = -47.661 + 11.220W$	0.9191	7.14	0.0001
(2)	$A = -39.082 + 13.729L$	0.8303	10.33	0.0001
(3)	$A = 2.568 + 0.593W^2$	0.9446	5.91	0.0001
(4)	$A = 6.844 + 0.967L^2$	0.8499	9.72	0.0001
(5)	$A = -50.245 + 8.329W + 4.178L$	0.9350	6.40	0.0001
(6)	$A = 0.490 + 0.428W^2 + 0.323L^2$	0.9672	4.55	0.2167
(7)	$A = 1.056 + 0.809WL$	0.9555	5.29	0.0219
(8)	$A = 0.672W^{1.963}$	0.9632	5.67	0.0001
(9)	$A = 1.527L^{1.830}$	0.8801	10.23	0.0001



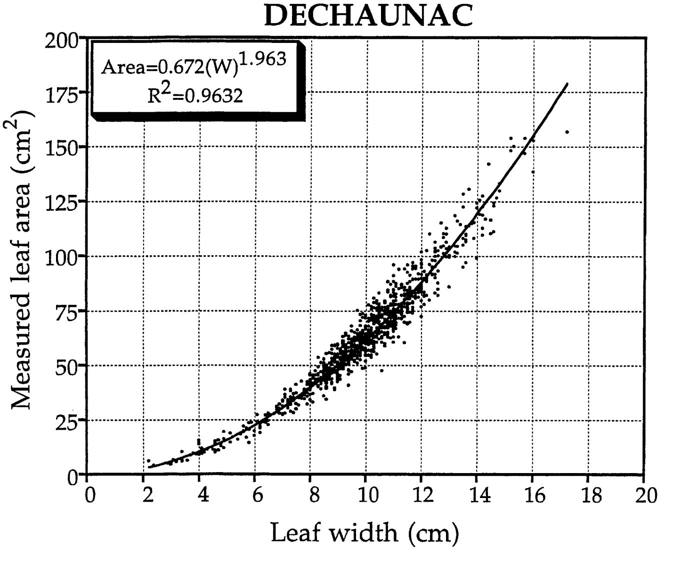


Fig. 1. Relationship between measured leaf area and maximum leaf width for 'Niagara' and 'DeChaunac' grapevines. Regression lines represent estimated leaf area derived from measured data (black dots).

using length alone. Fig. 1 presents the relationship between measured leaf area and maximum leaf width for Eq. (8) for both cultivars. Even though intercepts tested significantly different from zero in the power models for both cultivars, these differences were small in absolute terms (Fig. 1) and would not greatly affect the usefulness of these models.

4. Discussion

Our results were consistent with those of other studies that used linear measurements of grape leaves for estimating leaf area. Coefficients of determination were generally high ($R^2 > 0.95$) for the best-fit models in the current and previous studies. Elsner and Jubb (1988) reported two-variable models ($\text{area} = -1.41 + 0.527W^2 + 0.254L^2$, $R^2 = 0.988$ and $\text{area} = -3.01 + 0.85WL$, $R^2 = 0.984$) that best estimated leaf area of 'Concord' grapevines. These equations are similar to those of the current study for 'Niagara' leaves, and are not surprising given the similarities in size and shape between the two cultivars. Using 'Thompson Seedless' grapevines, Smith and Kliewer (1984) found that the product of maximum leaf length and width was most highly correlated with leaf area. In a study of *V. vinifera* L. grapes ('Chardonnay' and 'Chenin blanc'), Sepúlveda and Kliewer (1983) determined that the product of leaf length and width consistently resulted in the highest coefficients of determination of the models tested. Standard errors were 4.74 and 3.06 cm^2 for 'Chardonnay' and 'Chenin blanc', respectively. These estimates were comparable to those we obtained for 'DeChaunac' leaves, which are similar in size to 'Chardonnay' and 'Chenin blanc'. In another study using *V. vinifera*, Montero et al. (2000) reported that linear ($\text{area} = 0.587WL$, $R^2 = 0.987$) and power ($\text{area} = 0.647L^{1.956}$, $R^2 = 0.968$) models provided best estimates of 'Cencibel' leaf area. Manivel and Weaver (1974) reported that second-order polynomial models using either leaf length or width better fit 'Grenache' leaf area than linear models.

For 'Niagara' and 'DeChaunac' grapevines, the best single-variable regression equations for estimation of leaf area were power models incorporating leaf width. Best two-variable models used the squares of leaf width and length to estimate leaf area. Single-variable models avoid problems of collinearity between leaf width and length, and require measurement of only one leaf dimension, thus simplifying measurement procedures. Because maximum leaf width and midvein length are dimensions that can be easily measured in the field, use of these equations would enable researchers to make non-destructive measurements or repeated measurements on the same leaves. Such equations would also allow viticulturists to estimate leaf area in relation to factors like crop load, drought stress, and insect damage. In-field estimates of leaf area could be made using inexpensive programmable calculators.

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